COMPARATIVE STUDY OF INDOOR AIR CONTAMINANTS IN DIFFERENT STAGES OF NEW BUILDING OCCUPANCY: WORK ENVIRONMENT ASSESSMENT

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ABSTRACT

Indoor Air Quality (IAQ) is a part of Building Environment. Nowadays, the construction of new building took place over the world. Upon new building occupancy, a lot of indoors material was used without IAQ concern. This study has been conducted in a new constructed building of the National Institute of Occupational Safety and Health (NIOSH) Malaysia. The goal of the study is to monitor on the level of IAQ parameters including chemical and physical parameters within four consequent stages which are before furniture install, after furniture install and during one and three month occupancy. The indoor parameters have been measured consist of nine parameters including of Carbon Dioxide (CO_2), Carbon Monoxide (CO), Total Volatile Organic Compounds (TVOC), Formaldehyde, Respirable Particulates (PM_{10}), Ozone, Relative Humidity (RH), Temperature and Air Movement. The interaction between Malaysian and international standard was referred and utilized in collecting the data and analyzing of the findings. There was a significant correlation between the high values of RH, Formaldehyde and PM_{10} where (r 0.324, $p <0.05$), (r 0.344, $p <0.05$) and (r 0.319, $p<0.05$) with extension of phases of new building occupancy respectively. This study established significant different on Formaldehyde and Particulate Matter (PM_{10}) concentration level as go along with the building occupancy. These finding indicated that furniture and fittings, indoor materials and human population has a potential sources of indoor air contaminants. It is recommended that the management should be aware to their indoor air status to protect the occupant from the risk of unwanted exposure especially during the early stage of building occupancy. Finally this research has fully supported the Malaysian need to formulate of future guideline on IAQ commissioning and maintenance of new building occupancy.

ABSTRAK

Kualiti Udara Dalaman (IAQ) adalah sebahagian daripada persekitaran bangunan. Pada masa kini, pembinaan bangunan baru mengambil tempat di seluruh dunia. Terdapat banyak penggunaan bahan tanpa mengambil kira kepentingan IAQ sebaik sahaja bangunan baru diduduki. Kajian ini telah dijalankan di sebuah bangunan baru yang dibina di Institut Keselamatan dan Kesihatan Pekerjaan (NIOSH) Malaysia. Matlamat utama kajian ini adalah untuk memantau tahap beberapa parameter IAQ termasuk parameter fizikal dan kimia di dalam empat peringkat awal bangunan diduduki termasuk sebelum perabot dipasang, selepas pemasangan perabot dan semasa satu dan tiga bulan bangunan diduduki. Di antara parameter dalaman yang diukur terdiri daripada sembilan parameter termasuk Karbon Dioksida (CO_2), Karbon Monoksida (CO), Jumlah Sebatian Organik Meruap (TVOC), Formaldehid, Zarahan Ternafaskan (PM_{10}), Ozon , Kelembapan Relatif (RH) , Suhu Udara dan Pergerakan Udara. Interaksi di antara standard Malaysia dan antarabangsa dirujuk dan digunapakai bagi pengumpulan serta penilaian data dan penemuan. Terdapat hubungan yang ketara di antara peningkatan RH, Formaldehid dan PM_{10} menunjukkan (r 0.324, $p <0.05$), (r 0.344, $p <0.05$) dan (r 0.319, $p<0.05$) dengan lanjutan masa bangunan baru diduduki. Kajian ini memperlihatkan perbezaan yang ketara di antara kepekatan Formaldehid dan Zarahan Ternafaskan (PM_{10}) sepanjang fasa bangunan baru diduduki. Keputusan kajian ini menunjukkan bahawa perabot dan kelengkapan, bahan-bahan dalaman bangunan dan populasi manusia mungkin menjadi sumber potensi bahan pencemar udara dalaman bangunan. Pihak pengurusan bangunan perlu sedar terhadap status udara dalaman mereka untuk melindungi penghuni daripada risiko pendedahan yang tidak diingini terutama semasa peringkat awal bangunan baru diduduki. Akhir sekali kajian ini telah menyokong sepenuhnya keperluan Malaysia untuk merangka garis panduan pentauliahan dan penyelenggaraan IAQ bagi bangunan baru yang diduduki pada masa hadapan.

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LIST OF SYMBOLS AND ABBREVIATIONS

ASHRAE	-	American Society of Heating, Refrigeration, and Air Conditioning Engineers
BTEX	-	Benzene, Toluene, Ethylbenzene, and Xylene
CIDB	-	Construction Industry Development Board
CO	-	Carbon monoxide
CO_2	-	Carbon dioxide
COP	-	Code of Practice
CS	-	Cases Reported
DOSH	-	Department of Occupational Safety and Health
EPA	-	Environmental Protection Agency
FDI	-	Foreign Direct Investment
FLEC	-	Field and Laboratory Emission Cell
FMA	-	Factory and Machinery Act 1967
GDP	-	Gross Domestic Product
HIRARC	-	Hazard Identification, Risk Assessment and Risk Control
HVAC	-	Heating, Ventilation and Air Conditioning
IAC	-	Indoor Air Contaminants
IAP	-	Indoor Air Parameters
IAQ	-	Indoor Air Quality
IARC	-	International Agency for Research on Cancer
ICOP- IAQ	-	Industry Code of Practice on Indoor Air Quality
IPCC	-	Intergovernmental Panel on Climate Change
ISO	-	International Standard Organization
JRC	-	Joint Research Centre
LFPR	-	Labour Force Participation Rates

MC	-	Moisture Content
MS	-	Malaysian Standard
MVAC	-	Mechanical Ventilation and Air Conditioning
NIOSH	-	National Institute of Occupational Safety and Health
NO_2	-	Nitrogen Dioxide
OSH	-	Occupational Safety and Health
OSHA	-	Occupational Safety and Health Act 1994 (Act 514)
PDCS	-	Permanent Disability Cases Paid
PM_{10}	-	Particulate Matter
ppb	-	part per billion
ppm	-	part per million
PRD	-	Pearl River Delta
RH	-	Relative Humidity
SBS	-	Sick Building Syndrome
SMACNA	-	Sheet Metal and Air Conditioning Contractors National Association
SMI	-	Small and Medium Industries
SO_2	-	Sulphur Dioxide
SOCSO	-	Social Security Organization
SPM	-	Suspended Particulate Matter
SVOCs	-	Semi Volatile Organic Compounds
TBC	-	Total Bacteria Count
TFC	-	Total Fungus Count
TSP	-	Total Suspended Particulate
TVOC	-	Total Volatile Organic Compounds
USECHH	-	Use and Standard of Exposure of Chemicals Hazardous to Health Regulation,2000
UTHM	-	Universiti Tun Hussein Onn Malaysia
VOCs	-	Volatile Organic Compounds
VVOCs	-	Very Volatile Organic Compounds
WHO	-	World Health Organization

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CHAPTER 1

INTRODUCTION

1.1 Introduction

In this chapter, the background of the research problem is explained. The introduction to safety and health issues in industries are identified and related activities were discussed. Initially, it looks into major related economic development activities, social, and policy issues in the Malaysian scenario and how these issues relate to the safety and health problems. This chapter proceed with the problem statement for the study, based on the background provided, as well as the resulting research questions, objectives, limitations and the significance of the study. This chapter also highlighted the management of the whole thesis.

1.2 Background of the problem

Malaysia is one of the developing countries with a population of 30.0 million (Malaysia, 2013). Malaysia's population in 2009 was 27.9 million and having a labor force of 11.315 million. In 2013 the population increased to 30.0 million and labor force increased to 14.246 million, a growth close to 8.5% with 4.5-5.0% of Gross Domestic Product (GDP) growth. Table 1.1 shows Key Malaysian Economic Data from 2009 to 2013 extracted from the Malaysian Economic In Brief 2009/2013. (Malaysia, 2013)

Table 1.1: Key economic data 2009-2013
(The Malaysian Economy in Brief, 2009/2013(Malaysia, 2013))

YEAR	2009	2010	2011	2012	2013
Area (km^2)	330,803				
Population (million)					
Total	27.9	28.3	28.9	29.3	30.0[3]
Average Annual Population Growth Rate (%)	1.3	1.3	1.3	1.3	1.3[1]
Gross Domestic Product (GDP)					
GDP at current prices (RM million)	679,938	765,965	884,456	941,237	987,675[1]
GDP at constant prices (RM million)	522,001	559,554	711,351	751,471	786,596[1]
GDP Growth (%)	(1.6)	7.2	5.1	5.6	4.5~5.0[1]
Employment					
Labour Force ('000)	11,315.3	11,517.2	12,505.8	13,119.6	14,246.0[2]
Employed ('000)	10,897.3	11,129.4	12,123.0	12,723.2	12,851.8[2]
Unemployed ('000)	418.0	387.9	382.9	396.3	444.5[2]
Labour Force Participation Rates, LFPR (%)	62.9	62.7	64.1	65.5	65.6[2]
Unemployment Rate (%)	3.7	3.4	3.1	3.0	3.3[2]

[1] Estimates by Ministry of Finance, Malaysia
[2] As September 2013
[3] As Quarter three of year 2013
() Negative

Malaysia is rapidly growth in development of construction industries. The construction industry makes a significant contribution to the quality of life in the country. Over the past decade, the sector annually accounted for about 3-5% of the GDP and provided employment for about 10% of the total labor force. In addition, the construction industry also realizes many aspects of government policies aimed to develop the nation include to building of houses, schools, hospitals, roads, airports, ports and other transportation infrastructure. Although the construction sector is vital to the achievement of national socio-economic development goals of providing employment, shelter and infrastructure, it can be a significant source of negative impacts on the physical environment. Among the major impacts associated with the industry are soil erosion and sedimentation, flash floods, destruction of vegetation and dust pollution. Other impacts associated with the industry include depletion of natural resources and the use of building materials that are harmful to human health.

Based on Construction Industry Development Board (CIDB, 2013), Construction projects in Malaysia has been categorized by the product usage and not by construction activities. Table 1.2 below shows the number and value of project awarded as of September 2013.

Table 1.2: The number and value of project awarded 2011/2013 (Construction Statistics Quarterly Bulletin, CIDB, 2013)

Year/Type of Work	Total Number of Projects	Total Project Value (RM m)
2013	4,253[1]	66,787.62[1]
New Project	3,262[1]	60,081.12[1]
Repair	222[1]	961.58[1]
Upgrading	370[1]	2,742.36[1]
2012	7,542	122,720.58
New Project	5,947	112,134.65
Repair	246	1,605.15
Upgrading	516	3,143.38
2011	7,585	99,739.11
New Project	6,140	89,161.83
Repair	246	1,205.35
Upgrading	520	4,711.97

[1] As September 2013

The categories of constructions in Malaysia were categorized as Residential, Non-Residential, Social Amenities and Infrastructure (CIDB, 2013). From the given data, the number of new project covered almost 80% of the total new project every year. It was clearly shown the construction of new building in Malaysia is become the main building construction as compared to repair, upgrading and maintenance. This number of project will be concurrently increased with the rapidly growth of Malaysia economy (CIDB, 2014).

Although Malaysian industries growths are rapid and their expansion are fast, they still face challenges that influence their competitiveness. The current scenario, depicts the Malaysian industries are now facing challenges on safety and health awareness at workplace. This could be the evident from number of industrial accidents occurrences and the un-conducive work environment reported (SOCSO, 2012).

1.2.1 Safety and health awareness in workplace

The occupational safety and health policy is to provide a conducive working environment to safety and health in the workplace. Reasonable precautionary steps are taken so as to ensure that workers are prevented from injury or health hazard due to work activities being carried out by Department of Occupational Safety & Health (DOSH, 2009). Managing occupational safety and health at the work place is no different than managing other aspect of business. The exception is that it requires the commitment of the proprietor or owner to ensure the following three conditions at workplace as stated by Occupational Safety and Health Act (DOSH, 1994) exist. These are:

i) Should have a policy statement on occupational safety and health;
ii) Should have a plan for the implementation of Hazard Identification, Risk Assessment and Risk Control (HIRARC) including training and auditing and;
iii) Should take remedial action for any improvements to be made.

If safety and health awareness in workplace are improved, the number of accidents can be reduced or decreased (Nicholas and Wangel, 1991). This must be done through department influence which continuously operates on daily routine basis at workplace that can be implemented through:

i) Training to improve knowledge, attitude, and management that can result in good work practice and safety procedures. It is apparent that industries need the above three conditions to achieve ideal safety and health at workplace;
ii) Defining clear responsibilities and work ethics;
iii) Identifying and introducing practical solutions to the problem related to safety and health.

The implications for safety and health practice, the formulation of legislation and its enforcement in a global economy are considerable. Tools, machine, processes, raw materials, plant, buildings and the management system will have to be designed so that they are intrinsically safe and non-hazardous for the users. Safety and health will have to be integrated as part of the production process with its own quality assurance system. (Brune *et al.*,1997. ISO, 2009). This will require managers and supervisors to be highly trained in the management and administration of safety and health system and programs. As legislation continues to develop for the recognition, assessment and control of risks in the workplace; at the planning stage and at the design stage for products and equipment, the knowledge and skills of those involved will also have to be developed. To meet these demands, the training education on safety and health will eventually become a new sub industrial sector that will be closely associated with engineering and assist in identifying cost-effective ways of achieving control of risks.

1.2.2 Industrial accidents occurrence

Overall, the number of industrial accident occurrence is the major indicator for evaluation of the Occupational Safety and Health (OSH) program. The numbers of industrial accident for 2008 of were 54,133. In year 2012 the number was increased to 61,551. The number of occupational accidents reported increased by 7,418 cases or 13.7% within five years elapsed. From the total number of accidents reported in year 2012, 16,633 cases were due to indoor working environment including cases of environmentally factors such as ventilation, lighting, temperature and noise by Social Security Organization (SOCSO, 2012). Employers and employees really need to combine their efforts to reduce the number of accidents in industry specifically in the indoor workplace.

1.2.3 Unconducive work environment

There are many questions about the safety and health aspect of the working environment, and workers. Workers who spend about a quarter of their lives in the workplace must be aware of this situation (Brune *et al*., 1997). Ensuring a safe and healthy workplace require a joint effort with input from management and employees. While undoubtedly a win-win proposition, it is certainly not easy to ensure a safe and healthy workplace (Pingle, 2009). SOCSO categorized the work environment into three categories that are outdoor, indoor and underground. Table 1.3 shows the number of accident cases that are related to work environment.

Table 1.3: The statistic for accident causes related to work environment in 2012
(Table 10 – SOCSO, 2012)

Accident Causes		
Work Environment	CR	PDCS
Indoor		
• Floors	690	190
• Confined quarters	1,608	375
• Stairs	381	101
• Others traffic and working surfaces	2,907	632
• Floor opening and wall openings	1,050	307
• Environmental factor(lighting, ventilation, temperatures, noise, etc)	16	4
• Others	9,344	1,933

Note: CR – Cases Reported
PDCS- Permanent Disability Cases Paid

From the SOCSO Malaysia report (SOCSO, 2012), there are significant problems concerning working environment (i.e. environmental factors: Lighting, ventilation, temperatures and noise). A total of 16 cases were reported in year 2012. The number of industrial accidents by causing agent (i.e.: dusts, gases, liquids and chemicals) excluding explosives recorded 342 cases in 2012. The number has increased from year to year. The air borne contamination is one of the hazards that is associated in work environment. Failure to properly monitor measure and report hazardous airborne emission can cost a manufacturing company considerable amount of money to pay the associated fines as reported in Danbury, Connecticut, the United States of America. A company was fined $218,000 in levied reported in the Environmental Protection Agency (Goetsch, 2008).

From the unconducive work environment, the related issues on the workers safety and health have grown. Sickness absenteeism is a significant problem both for employees and for employers (Martimo, 2006). As preventive measures, it is important to recognize the situation and factors that can cause psychological overload at work. Rapid workforces, pressure from employer, continuous changes at work are often listed as a stress factor (Rantanen and Lethinen, 1999). The health status of workers in small companies has been noted to be relatively poor (Yamataki *et al*., 2006). However in large organizations, safe behavior programs are currently a popular strategy for improving safety (Hopkins, 2006). Sometimes the discussions on safety and health are more directed towards the economic consequences rather than individual suffering caused by disabling diseases (Martimo, 2006). Another aspect that may contribute to unconducive work environment is Indoor Air Quality (IAQ). Increased awareness of the poor quality of indoor air compared to the outdoor air has resulted in a significant amount of research on the adverse health effects and mechanism of action of indoor air pollutants (Zummo and Karol, 1996).

1.3 The problem statement

Air pollution in the past has not been regarded as serious problems in Malaysia. However, since the shift in the nation's development strategy from agriculture to manufacturing and heavy industries, there has been an increase in the generation of pollutants and industrial waste thus resulting in the deterioration of the country's air quality. This has become a serious concern particularly when the climate in this part of the world has shown to have a high potential of air pollution. This is evident from a study done for long term observation on the trends of major air pollutants in Malaysia which includes Nitrogen Dioxide (NO_2), Carbon Monoxide (CO), ground level Ozone (O_3), Total Suspended Particulate (TSP) particularly Respirable Particulate or Particulate Matter (PM_{10}) and Sulphur Dioxide (SO_2) emitted from industrial and urban areas from early 1970s (Latif *et al.*, 2006). The data showed that the states of atmospheric environment in Malaysia, particularly within industrialized areas were caused both by emissions from local and transboundry. Local emissions are the pollutants that come from local activities and transboundry emissions are from the neighboring countries like Indonesia, Thailand and Philipines (Ibrahim *et al.*, 2006).

The Malaysian Government has introduced a guideline on monitoring of airborne contaminants for chemicals hazardous to health by DOSH Malaysia 2002. However from the observations and case studies conducted, it was noticed that monitoring process has not been given priority due to insufficient of measuring equipment, hence the toxic gases were not measured in the work place (Leman *et al.*, 2006, 2008 and 2009).In providing solutions to traceable problems, it is necessary to conduct a monitoring of IAQ and the assessment in the building.

Hence the primary research questions being investigated in this research are:

i) Does the introduction of IAQ assessment, measurements and monitoring program able to improve the Occupational Safety and Health (OSH) factor related to indoor air exposure in the building?

ii) Does the indoor air pollution bring in during new building construction can be mitigated as earlier stage of development phase in the construction industries?

1.4 Research objectives and goals

The main objectives of the research are follows:-

i) To measure the nine IAQ parameters during commissioning of new building (The phases can be before furniture install, after furniture install and during one month occupancy). In addition to observed the potential sources of indoor air exposures by strategically plan the monitoring program.

ii) To identify the nine IAQ parameters data differences among the above three phases of building occupancy. Performing the comparison data among the three phases will significantly show the importance of controlling the factors contributes to indoor air exposures from the earlier stage of building occupancy.

iii) To analyze the differences of the three phases data with the following phase which is three months building occupancy for five selected IAQ parameters including Temperature, Relative Humidity (RH), Air Movements, Formaldehyde and PM_{10} and determine the correlation of effect of human activity in contributing to the Indoor Air Contaminants (IAC).

1.5 Scope of the research

A building of the National Institute of Occupational Safety and Health (NIOSH) Malaysia was selected as sample for this research for its nature of a typical office and training center. Besides that, NIOSH has new building in placed called NIOSH Tower as the reference of this study. Refer to the below figure 1.1 show the NIOSH Tower Building after completion of the construction. The proposed allocation of the nine-storey building facilities represent the typical setting of Malaysian offices. Comparison among the setting can be studied and relation can be achieved.

Figure 1.1: NIOSH Tower building in Bandar Baru Bangi, Selangor

Since NIOSH Tower is located at the urban city of Bandar Baru Bangi, Selangor, Malaysia. It was also designed with the new architecture plan as this building construction completed in year 2011. Data gathered in this research in some way can be generalized with other Malaysian buildings which has similar designed and setting with NIOSH Tower.

The study identified the Indoor Air Contaminants (IAC) including physical and chemical parameters as the subjects to be monitored. A total of nine parameters were selected based on the establish standard available in Malaysia called ICOP-IAQ by Department of Occupational Safety and Health (DOSH), Malaysia. The nine IAQ parameters including of Temperature, Relative Humidity (RH), Air Movements, Carbon Dioxide (CO_2), Carbon Monoxide (CO), Total Volatile Organic Compounds (TVOC), Ozone, Formaldehyde and Particulates Matter (PM_{10}).

1.6 Significance of the study

The study is anticipated to benefits three sectors namely the industry, (employer and employees), the government and the education sector.

1.6.1 Industry (employer and employees)

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